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Venture Capital Investment in the Clean Energy Sector

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1. Introduction

Venture capital has been a key source of finance for commercializing radical innovations in the United States, particularly over the last three decades. The emergence of new industries such as semi-conductors, biotechnology and the internet, as well as the introduction of several innovations across a spectrum of sectors in healthcare, IT and new materials have been driven in large part by the availability of venture capital for new startups. Unlike other forms of external finance, a key aspect of venture capital is that it facilitates the provision of funding to startup firms despite the huge risks associated with unproven technologies (Gompers and Lerner 1999). Since startups with new technologies rarely have internal cash flow to draw upon and are too risky to get debt finance, they depend critically on the provision of venture capital for their survival.

In this chapter, we examine the extent to which venture capital is adequately positioned for the rapid commercialization of clean energy technologies in the United States. The need for a revolution in clean energy is driven not just by environmental consequences of energy use, but also by the need for energy security, to address growing concerns about a crisis in the balance of payments, and as a potentially important source of domestic jobs. Our premise in this chapter is that a key aspect of such widespread change is that these issues cannot be "solved" by a single technology. Rather, technological changes will have to be pervasive and will require a whole range of different products and processes to come to market. Some of the technological progress will come from incremental innovations that do not depend on venture capital. For example, the large scale deployment of more mature technologies such as wind farms or utility-scale solar is funded through project finance. Moreover, firms manufacturing the wind turbines and solar modules are able to fund their growth through debt or the stock market. Other solutions such as retrofitting homes and office spaces with more energy efficient materials can be funded through bank finance.

However, a range of new startups in the energy production, transportation, energy-storage and energy-efficiency sub-sectors depend critically on venture capital for their commercialization because their technologies and business models are not yet proven. It is the VC funding of these projects and the potential challenges therein, that is the focus of this chapter.[1]

We document a range of factors about these clean technology startups that make them much more challenging from an investment standpoint than the typical investment made by VC firms. These challenges have begun to impact the focus of VC investments in clean energy and are likely to continue doing so in the near future. In particular, VC investments have begun to move away from radical technologies related to energy production and are increasingly focused on energy efficiency, software, energy-storage and transportation. Startups in these latter sectors tend to be closer to the traditional investments VCs make, in terms of their capital intensity, exit requirements and business models. Even for investments in energy production, VCs have begun shifting the business models of their portfolio companies towards component manufacturing -- that is much closer to their traditional focus and expertise than the skills required to build energy production companies. In the long-term, sustained venture investment in startups focused on energy production will depend on the ability of venture capitalists to find workable solutions to the investment hurdles they face. We highlight, based on historical evidence, that overcoming such hurdles can take a significant amount of time and is not guaranteed to succeed.

A key attribute of the venture-backed innovation in the US has been the ability of the private capital markets to finance a wide variety of approaches in a specific area, as opposed to choosing winners early. Since venture capital is the primary source of "risk capital" available to clean energy startups in the US, the changing focus of VC investment in clean energy can have important consequences for the nature of US innovation in this space (Kortum and Lerner 2000). In the long term, it could imply that the locus of innovation in energy production may move away from the US to Europe or to China, driven by the more aggressive government policies in those regions aimed at promoting private investment in clean energy production. We therefore also highlight US government policies that may help to mitigate the challenges faced by VCs, as well as accelerate the institutionalization of venture investment in the clean energy space.

Our analysis is based on both a quantitative study of recent venture capital deals, as well discussions with several leading venture capital investors. In some cases, VCs we spoke to had

[1] This does not in any way imply that the other sources of innovation are unimportant or that the other forms of finance for these sectors do not face their set of challenges. They are simply outside the scope of this chapter. Likewise, we do not take a position on the relative importance of incremental vs. radical innovations for the US to focus on. We take as given that both are necessary, and given this, examine the hurdles facing the venture capital community in commercializing radical innovations in clean technology.

made initial investments in the sector, but subsequently decided to curtail their investments because of actual or perceived difficulties in making adequate returns. We also spoke with active VC investors who had chosen not to invest in (certain types of) clean energy startups. As such, our analysis is also “forward-looking” in terms of the expectations that these individuals have about VC investment in this sector going forward.

To put the challenges we note in context, we first outline the processes that VC firms have developed to make them uniquely qualified to foster innovation in an uncertain environment. In Sections 3 and 4 we show how these processes are poorly suited to funding certain types of clean energy startups. Section 5 outlines some possible solutions to the challenges, including the role of government policy. Section 6 has conclusions.

2. Distinguishing Features of Venture Capital Investments

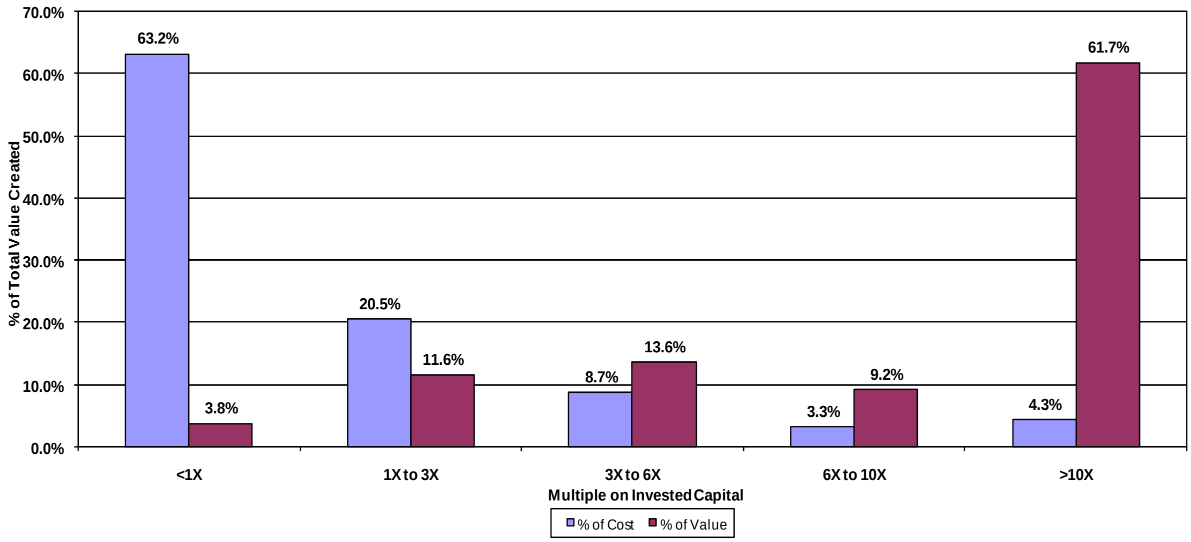
2.1 Portfolio Strategy

A key difference between venture capital (VC) and other sources of finance is that VC firms tend to focus on investments that face substantial technology risk. Moreover, the technology risk is not resolved until the VCs have made significant investments in the startup, which means that VCs may have invested sizeable sums of money before it ends up being a failure. Together, these features lead to a highly skewed distribution of returns in venture capitalists’ portfolios.

Figure 1 documents an example of these skewed returns for a leading VC firm. As can be seen from Figure 1, 8% of the dollars invested by this VC firm accounted for over 70% of the overall returns of the portfolio. On the other hand, 60% of the dollars invested were spent on projects that were ultimately terminated below the cost of the investment, and hence contributed to under 4% of the returns of the portfolio.[2] It is important to note that at the time of the initial investment, of course, all their investments had the potential to realize exceptional returns. Indeed, given the high chance of failure, VCs will not invest in projects that do not have the potential to be “winners”. They just do not know which of their investments will end up as winners and which ones will end up being failures. Put differently, the return distribution for VCs looks like that in Figure 1 *in expectation,* even though each individual investment is made with the belief that it could be a winner.

[2] Data on venture capital investments tends to be private so that a large-scale analysis is difficult to document. Moreover funds with investments primarily in software have somewhat different return profiles than those in more capital intensive sectors such as biotechnology. However, discussions with investors reveal that skewed distributions highlighted in Figure 1 are a common feature in venture portfolios, even for the best venture funds.

Figure 1: Breakdown of a Tier 1 VC's Portfolio



Source: Analysis by Professor William Sahlman, based on 468 Investments for the fund from 1990- 2006

An important facet of the venture capitalists' investment process therefore involves a large enough number of investments in the portfolio so that the chance of a positive "tail outcome" in the portfolio increases. It therefore follows that any individual investment cannot be too capital intensive relative to the size of the fund. In fact, most funds have formal restrictions that constrain the amount of capital that the VC firm can invest in a single project. Figure 2 shows what the planned investments look like for a typical $300 M venture fund. It highlights the fact that since VCs *plan* to only make money from half of their investments, they need a few of their investments to do very well *as well as* own a reasonable share of those firms at exit, in order for the VC to generate strong dollar returns.

Figure 2: Example of Pro-Forma shown by VCs to their investors

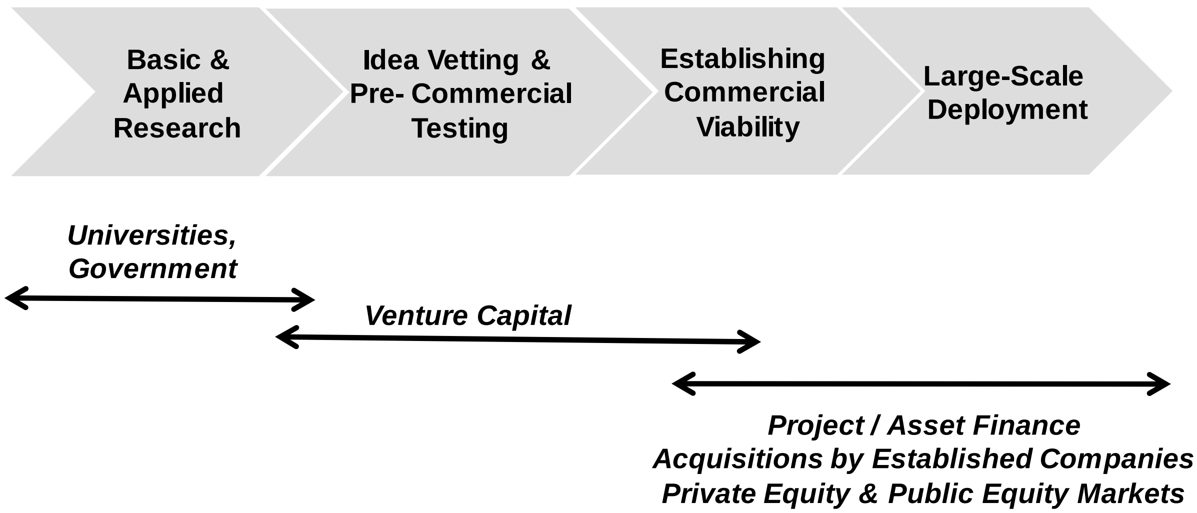
Category of Outcome	Projected Value at Exit	Dollar invested per company	Share owned at Exit	Expected # investments	Total $ invested	Total $ Return
Early Failure	-	$ 5 M	n/a	5	$ 25 M	0
Complete write off	-	$ 8-15 M	n/a	5	$ 55 M	0
Money back	$ 50 M	$ 8-15 M	20%	5	$ 55 M	$ 50 M
Successful exit (low)	$ 200 M	$ 8-15 M	20%	5	$ 55 M	$ 200 M
Successful exit (medium)	$ 350 M	$ 8-15 M	20%	5	$ 55 M	$ 350 M
Successful exit (high)	$ 500 M	$ 8-15 M	20%	5	$ 55 M	$ 500 M
Total					$ 300 M	$ 1,100 M

Source: Authors' analysis based on discussions with VCs

VCs are often most comfortable investing in less capital intensive sectors, and/or focus early in the stage of the firm's life cycle where the capital needs are smaller, in order to have a lower overall investment in the firm, while still retaining a large share of equity. This is outlined in Figure 3 below. Figure 3 shows that VCs focus on the pre-commercial stages of the firm's life cycle, and up till the point where commercial viability has been established. At this point, they often "exit" their investment, either through a sale to established companies in the sector, or through the public equity markets.[3]

[3] Since individual VC firms have limits on how much they can invest in a given portfolio company, they need to have some assurance that the project can be handed over to another investor if the these financing limits have been reached but the startup has not yet achieved an IPO or sale (Nanda and Rhodes-Kropf 2010). Thus, even within the pre-commercial stage of the firm's life cycle, VC firms specialize in somewhat different sub-stages, with some investors focusing on seed and early stage investments, while other coming in at higher valuations after the initial risk has been minimized but prior to establishing commercial viability.

Figure 3: Stage of VC Investments



2.2 Governance

The skills required to run early stage companies are very different from those required to manage large corporations. A second important aspect of venture capital is therefore the set of skills and contacts VC investors bring to bear on their investments. By ensuring that the startup is making progress as expected and helping to remove roadblocks, VCs reduce the operational risk of the startup and increase its chances of success. The governance provided by VC investors is thus a key attribute of venture capital compared to other sources of finance and is also believed to be a source of competitive advantage across venture capital investors (Hsu 2004; Kaplan and Schoar 2005; Sorensen 2007).

Although VCs play an important role in governance through their positions on the board of portfolio companies, the day-to-day management in the firm still requires an able CEO. This implies that a key element in the success of a VC investment is the quality and track-record of the entrepreneurs who will run the company. VCs thus look for entrepreneurs with both industry experience and prior history of working in startups, so that they can successfully manage and grow the company to a point where it exits. In fact, a key asset of successful VCs is their stable network of management talent that can be brought into support an opportunity that is outside the scope of the current management (Hellman and Puri, 2002).

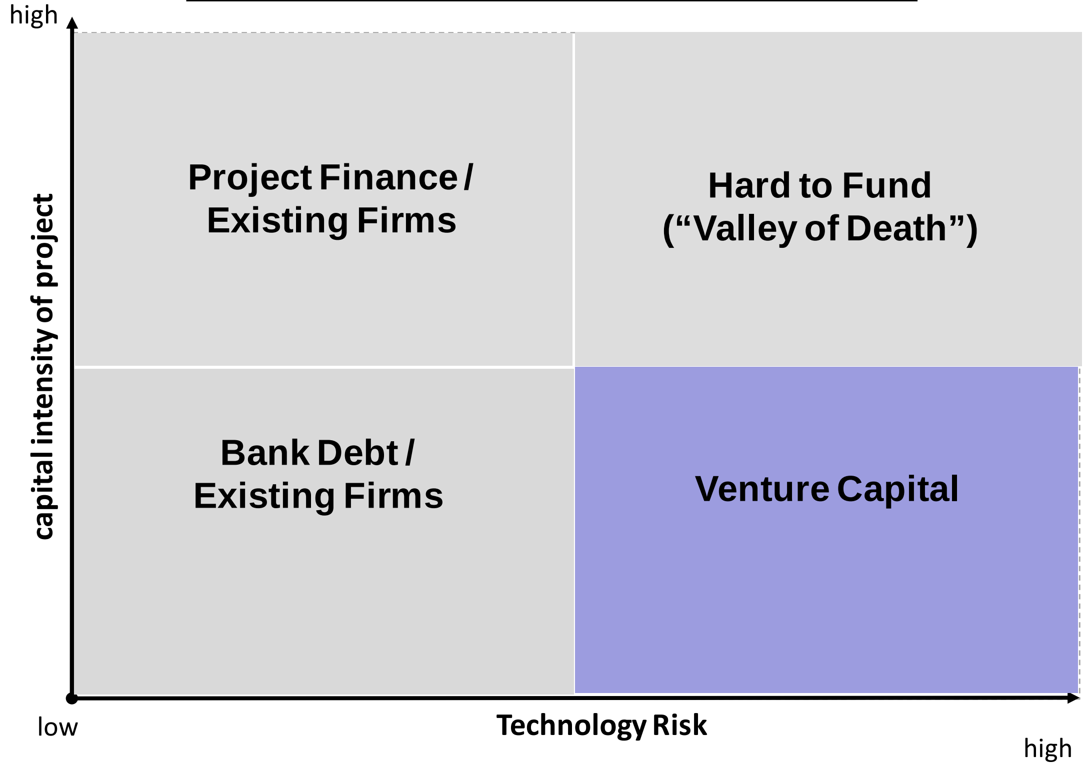
2.3 Contracts

Despite the focus on selecting good teams and governance, many VC investments fail due to the high technology risk. VCs therefore structure their investments using contracts such as convertible preferred stock --that gives them some measure of downside protection in the event that the investment fails, while still giving them a chance to share in the upside if the firm succeeds (Gompers and Lerner 1999; Kaplan and Stromberg 2003). VCs also stage their investments, giving the firm enough capital to reach its next "milestone", but make the next round of funding contingent on the progress made by the firm up until that point (Gompers 1995). Since a large number of their investments will fail after demonstrating early potential, VCs only make follow-on investments for firms that continue to look promising at each stage, thereby focusing their capital and time on the potential successes, as opposed to dividing it equally across all firms.

VC funds are structured to have a life of 10 years. Since the managing partners' compensation is based on a management fee (typically 2% of the committed capital) and a bonus for a strong return above a hurdle rate of return (known as carried interest, and typically 20% of the excess return), VCs like to exit their investment well within the 10-year period. This allows them to establish a clear track record with their own investors and hence raise a follow-on fund by the time investments in the prior fund are being harvested. VCs therefore have a bias towards investing in projects where the commercial viability is established within a three to five year period, so that they can exit through an acquisition or through an IPO within the life of a fund (Gompers and Lerner 1999).

Looking at Figure 4, it can be seen that the "sweet spot" for venture capital investment is therefore in the lower right hand box that is typified by high technology risk, but low capital intensity (Kerr and Nanda 2010). VCs have honed the art of investing in technologically risky projects, but the fact that they need to make many investments to realize a few successes implies they typically invest under $ 10-15 M in equity per startup. Sectors such as IT and software, that have relatively low levels of capital investment, are ideal sectors for VCs, where a syndicate of two to three investors can completely fund a startup through to IPO. In addition to their lower capital requirements, these sectors have shorter sales cycles that generate commercial viability quickly, hence enabling VCs to quickly grow their portfolio companies through the first three stages outlined in Figure 3, and exit their investments in a shorter period of time. In fact, the high returns for several of the most successful VC firms are based their Internet and IT investments. A classic example is that of Google, that had an IPO 5 years after it received its first round of VC funding and having raised about $40 M in venture capital.

Figure 4: Focus of VC investments



3. Venture Capital Investments in Clean Energy

Venture capital funding of clean energy startups has grown dramatically in absolute terms over the last decade.[4] In 2002, only 43 clean energy startups received VC funding in the US, raising a combined total of $ 230 M. In 2008, over 200 startups raised $ 4.1 BN in venture capital in the US.[5] In fact, clean energy investments accounted for about 15 % of the total dollars invested by VCs in the US in 2008.

Despite this growing interest in the sector, the number of venture capital firms with a strong focus on clean energy remains small. Less than 30 US VCs have a substantial portion of their portfolio targeted towards clean energy investments. This implies that a concentrated set of investors make the majority of the investments. For example, in 2008 and 2009, the top 5 VC

[4] Given that venture capital is focused on early stage and less capital intensive investments, it necessarily constitutes a small fraction of the total private capital invested in any sector. This is equally true of clean-energy, where less than 5% of the $ 500 BN in new investment from 2007-2009 was Venture Capital and Private Equity investment. (Calculations based on data from New Energy Finance.)

[5] Source: Ernst and Young, National Venture Capital Association Press Releases.

investors in clean energy accounted for about 25% of all the clean energy deals done by VCs in the US.[6]

Figure 5: Sub-Sectors within Clean Energy

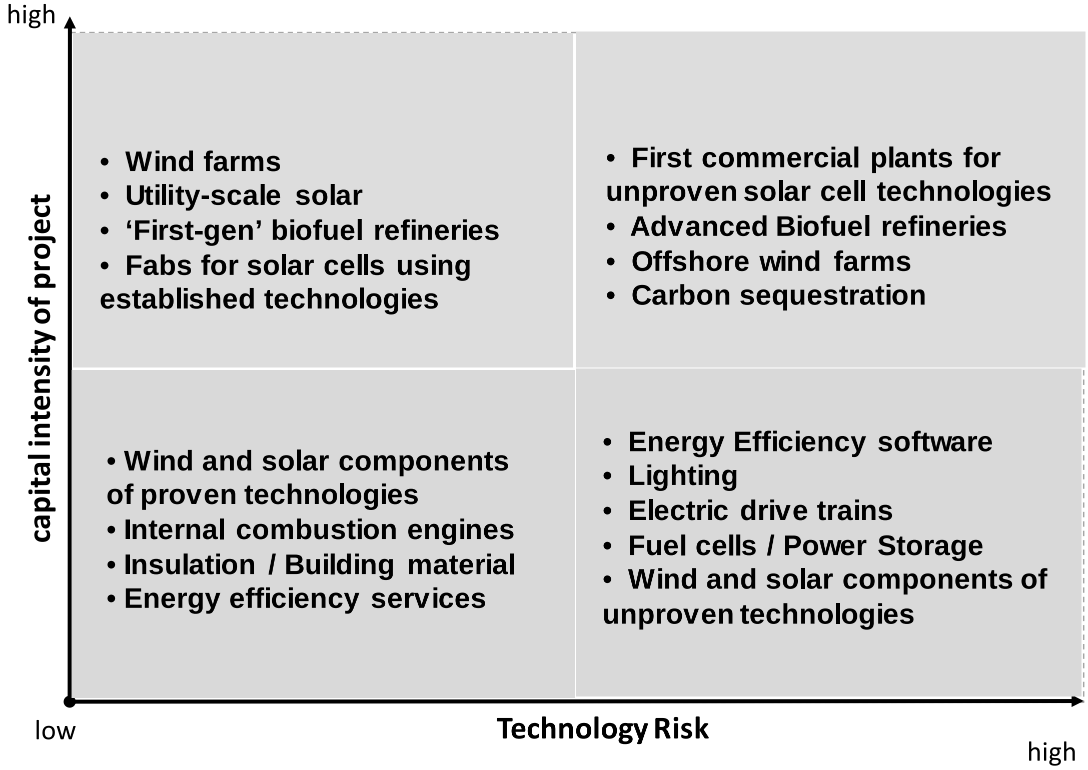


Figure 5 describes the clean energy investment landscape, mapped on to the framework outlined in Figure 4. The top left hand box outlines the manufacture and deployment of more mature energy production technologies. The technology risk for these is minimal after the equipment has been commercially proven at scale, but yet is extremely expensive to finance. Since raising hundreds of millions of dollars of equity finance is extremely dilutive to private manufacturers and developers, they would prefer to raise debt finance for these large capital investments. Indeed, debt investors are willing to invest large sums of money once technologies have been tried and tested over a period of a few years. For example, over 50% of the $ 500 BN in new investment in clean technologies globally between 2007 and 2009 was from project finance of mature technologies such as wind turbines, solar panels, and first generation biofuel refineries, despite the challenges faced by the global capital markets during the recession.[7] Similarly, debt and equity markets will finance the capital investments needed

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[6] Authors' calculations based on data from New Energy Finance reports and the VentureXpert database.

[7] Authors' calculations based on data from New Energy Finance.

to support the growth of firms such as SunTech or First Solar that produce these commercially proven technologies.

The bottom left hand box describes less capital intensive, less risky businesses, or the manufacture of components for existing technologies that are used for energy production. Several of these relate to incremental innovations being undertaken within existing companies that have achieved and continue to achieve lower costs for their products. For example, General Electric, which is a leader in the wind turbine market, is continuously working on incremental innovations to reduce the cost and increase the efficiency of its products. In addition, several businesses relating to energy services or energy efficient building materials are emerging, driven by legislation to promote home and commercial retrofits. These businesses do not face technology risk, and can easily raise bank debt to fund their operations.[8]

On the other hand, the technologies in the two right hand boxes typically are too technologically risky to attract debt finance. The bureaucratic structure of large corporations often implies that such innovation is done by startups as opposed to larger firms (Henderson and Clark 1990.) The only way they can thus be commercialized is through initial investment from venture capital, as they do not have internal cash flow to fund their innovation and are too risky for project or debt finance.

After an initial foray into backing technologies in *both* the top and bottom right hand boxes, VCs are increasingly changing their focus towards only backing startups in the lower right hand box. That is, they are focusing on sectors that lie more in their traditional sweet spot as shown in Figure 4. For example, the share of energy efficiency deals done by VCs rose from 24% in 2008 to 32% in 2009 while energy production investments fell from 30% to 18%, and investments in alternative fuels fell from 13% to 8%.[9] Even among the projects that are related to energy production, VCs have begun changing their focus towards component manufacturers rather than full-scale energy producers. Discussions with VCs suggest that this trend is likely to continue and that several factors are contributing to this shift in focus. We outline these in greater detail in the section below.

[8] Even if they did seek venture capital, they are unlikely to have the growth potential that can offer VCs tail outcomes.
[9] Source: Ernst and Young press releases.

4. Clean Energy Investment Challenges facing VCs

4.1 Capital intensity of energy production and the "Valley of Death"

A key aspect of the *energy production* technologies in the top right hand box is that they face technology risks at two stages of their commercialization. The first, which is the risk of the technology working, is shared with other startups. However, these technologies face a second risk: even if the technology works in the lab, it is not clear if it will work at scale.

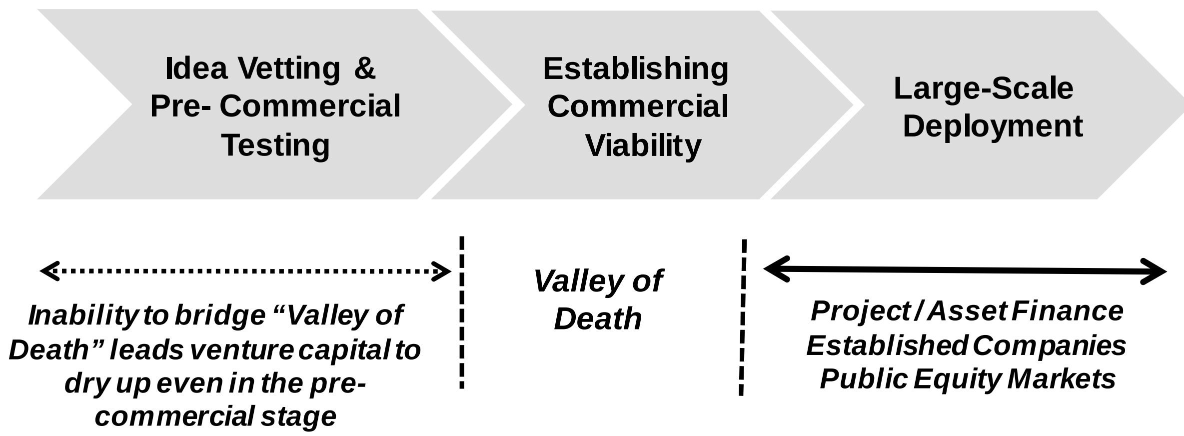
This implies that the technology risk for energy production companies remains for much longer than in most firms that VCs invest in. It also implies that risk capital is not just necessary for the early stages of the firm's life, but is also needed to demonstrate that the technology works at scale. Demonstration and first commercial plants for energy production are very capital intensive: the funds required to prove commercial viability for energy production technologies outlined in the top right hand box of Figure 4 can reach several hundred million dollars over a 5-10 year period, compared to the tens of millions that VCs are typically used to investing in any given startup. For example, Solyndra, a company that manufacturers photovoltaic systems using thin-film technology, has had to raise $ 970 M in equity finance in addition to a $ 535 M loan guarantee from the Department of Energy, *prior* to its planned IPO in mid 2010. This amount of capital to prove commercial viability is an order of magnitude greater than the $40-$50 M that VCs are typically used to investing in each company to get them to a successful exit.

As outlined in Figure 2, this level of investment is just not feasible from a $300 M fund without severely compromising the fund dynamics of a venture firm. For example, investing only $8-15M in project that is twice as capital intensive halves the dollar return, while maintaining the same share at exit in order to get the dollar returns requires making far fewer investments and hence makes the portfolio much more risky. Such investments are thus typically too capital intensive for VCs, given fund structures present today. On the other hand, these startups are still too risky for debt and project finance investors to fund their demonstration or first commercial plants. Debt investors are able to deploy large sums of capital, but require commercial viability to have been established well before they make their investments.

Thus ,while many startups face the risk that they may not receive enough early stage capital to get them past the pre-commercial stage, energy production startups, in particular, face a massive funding gap around the demonstration and first commercial stages of the project. The funding gap that arises at the commercialization stage has been referred to as the "valley of death" as shown in Figure 6 below. While a few startups such as First Solar (that had private funding from deep-pocked investors, including the Walton family) and Solyndra have been able to raise this capital, several firms that were backed by VCs in this sector have not been able to raise sufficient follow-on funding, even when their technology has looked promising.[10]

Another way of depicting the valley of death is through the framework in Figures 3 and 4. It highlights the fact that startups in the upper right hand corner -- that have the two stage investment risk and hence are too risky for project finance and too capital intensive for venture capital – are precisely the ones that risk falling into the “valley of death”.

Figure 6: Funding Gaps and “Valley of Death”



4.2 Managerial “Valley of Death”

While much of the focus of investors and policy makers has been on the challenges of *financing* the scale up, it is important to note, however, that it is not just a capital gap that is faced by energy production startups. Potential entrepreneurs who know the energy space often tend to be from large oil companies or from utilities. Their expertise is in running large, established firms that do not face much competitive pressure and have large cash flows at their disposal. Hence, they make good CEOs for the stage when the startup is more established, but they tend to be relatively poor entrepreneurs at the early stage of the business where cash is limited and needs to be raised frequently, the business model is not clear, and decisions need to be made quickly with limited information at hand. On the other hand, those with a background of VC

[10] Indeed the fact that Solyndra needed to withdraw its IPO is supportive of the fact that even for a firm that has successfully raised millions of dollars in VC funds, an exit is not guaranteed. This will only serve to further exacerbate the challenges faced by similar startups in raising venture capital.

backed entrepreneurship may be successful at running small IT-related, biotech or semi-conductor startups, but are ill-positioned to manage and grow energy production companies that have different business models and challenges. Since VCs require entrepreneurs to play a central role in fundraising for the large amounts of money required for commercial testing of the technology, in addition to managing large production facilities, international commodity pricing and anticipating the changing government policies, the skill set required of such CEOs is one that is in short supply.

Hence, VCs have begun to identify a "managerial valley of death" as well. There are managers with expertise in deployment and entrepreneurs with expertise in the initial idea vetting stage, but given the longer time taken for energy production startups to exit, the entrepreneurs who can successfully bridge the valley of death in the capital markets are few and far between. This mismatch between the requirements of an entrepreneur in the energy production space and the skill-set of the typical VC-backed entrepreneur is exacerbated by the fact that current VCs are also ill-positioned to act as mentors and help with the governance of energy production startups. Since most of the current successful VC investors have themselves made their mark investing in the IT sector, their knowledge about the needs around building a successful companies, their contacts to help startups with suppliers, customers and potential acquisition targets are not geared towards the energy production sector. All these factors greatly increase the operational risk of companies, and hence this creates important challenges for running and growing stand-alone energy production companies that go well beyond their capital intensity.

4.3 No established Exit Mechanism

In industries such as biotechnology, semiconductors and IT/ networks that also share the attributes of huge infrastructure and management requirements that are outside the scope of a startup, VCs bank on an established exit mechanism to hand over their early stage investments before they hit the valleys of death in capital and managerial talent. For example, in the biotechnology industry, the VC model has evolved so that pharmaceutical companies step in to buy promising startups at a point even before commercial viability has been proven. This is a key part of the innovation ecosystem as it bridges the potential valley of death and thereby facilitates pre-commercial VC investments in biotechnology. The propensity of pharmaceutical companies to buy promising startups also facilitates their IPOs at pre-commercial stages, because public investors believe there is sufficient competition among pharmaceutical firms for biotechnology startups with innovative solutions that they will be acquired well before they hit the valley of death. Cisco, Lucent, HP and Juniper networks play an equivalent role in the IT/ networking industry.

Thus far, however, energy producing firms and utilities that supply electricity to customers have been far from active in acquiring promising clean energy startups. This bottleneck in the scaling-up process has a knock-on effect on the ability for VCs to fund pre-commercial technologies in this space as well. If early stage venture investors face the risk that they may be unable to raise follow-on funding or to achieve an exit, even for startups with otherwise good (but as yet unproven) technologies, they run the danger of sinking increasing amounts of dollars for longer periods of time to keep the startup alive. With incumbent firms unwilling to buy these startups at pre-commercial stages, the time to exit for the typical startup is much longer than the three to five year horizon that VCs typically target (the time to build power plants and factories is inherently longer than a software sales cycle and can even take longer than the life of a VC fund). As shown in Figure 6, this leads venture capitalists to withdraw from sectors where they could have helped with the pre-commercial funding, but where they are not certain that they will be able to either fund the project through the first commercial plant, or they are not sure if they can exit their investment at that stage (Nanda and Rhodes-Kropf 2010).

In the case of biotechnology industry, a clear exit mechanism was facilitated by the fact that pharmaceutical companies had the capabilities for chemistry- rather than the new biology-based innovation being undertaken by biotechnology startups. Their own innovation pipelines had begun to dry up, and hence biotechnology startups provided a natural complement to their own expertise. Despite this "pull factor", pharmaceutical firms did not begin to actively acquire biotechnology startups until the latter began to actively compete with the pharmaceutical industry. Firms such as Biogen, Amgen and Genentech created a sense of urgency among the pharmaceutical industry, that also created a "push" to start acquiring such firms.

Because the set of buyers is uniform and the criteria for a successful exit at this stage have been developed and well-understood, VCs can work backwards and set their own investment milestones. In this way, the downstream exit process has important consequences for the direction of upstream innovation. The fact that there is a well developed eco-system where large pharmaceutical firms buy promising startups implies that there greater early stage venture capital funding of such firms. Moreover, stock market investors also have an appetite for such firms, in the knowledge that pharmaceutical firms will be willing to acquire a promising target before it hits the bottleneck of marketing and distribution. This in turn creates another exit avenue for venture investors, fuelling further early stage activity. In fact, the history of capital intensive industries such as biotechnology, communications networking and semiconductors suggests that until the incumbents start buying startups, the innovation pipeline does not truly take off.

The extent to which large energy companies will play an equivalent role in the innovation pipeline for clean energy is not yet clear. Oil companies have not chosen to be active buyers of clean technology startups. The quip “we spill more oil in a day than you manufacture using renewable feedstock in a year” typifies the attitude that entrepreneurs and VCs believe that oil companies have. While many such incumbents have chosen to invest in renewable technologies, these efforts have largely been seen as effective marketing rather than substantive efforts at alterative energy production that would cannibalize their core business. Similarly, the current incentive system for utilities where they are paid on electricity sales gives them no incentive to save energy or to adopt energy efficient technologies. Even when they are mandated to do so through quotas such as the Renewable Portfolio Standards or through decoupling, the incentives they face will push them towards using the safest, lowest cost technologies as opposed to buying riskier startup firms. Although there are a range of solar and wind energy startups that have themselves reached the “incumbency” stage, they are yet to become active buyers of other startups in their respective sub-sectors.

The lack of exit opportunities is not just an issue for energy production startups. Other sub-sectors in clean energy are equally vulnerable to the lack of a sustained exit mechanism. Many of the energy efficiency technologies related to smart meters depend on acquisition by, or cooperation of, incumbents for their success. Others depend on system-level change for widespread adoption. For example, smart grid software technologies are most effective once the antiquated electricity grid has been upgraded. Widespread adoption of electric vehicles will require complementary infrastructure such as charging stations. Innovation in the energy storage sub-sector also depends on the ability of incumbents to become active buyers of new startups. While not as extensive as the problems faced by energy production startups, these challenges may also hinder the longer-term success of venture investment in the clean energy investments in the bottom right hand box of Figure 4 as well as the top right hand box associated with the energy production technologies.

4.4 Global Commodities and Policy Risk

It is worth noting that the biotechnology industry took over 10-15 years to reach a point of institutionalization where pharmaceutical firms and VC backed startups each play their role in the innovation eco-system. The clean energy industry today is where biotechnology was in 1982 and the communications /networking industry was in 1988.

An important difference between the energy production and the typical VC-backed startup is that energy is a commodity. While incumbents in other industries compete with each other to acquire startups in order to meet end-user demand, the end-user in the energy market cannot distinguish electrons produced from coal, the sun or the wind (unless the government prices the cost of carbon appropriately). Incumbents are therefore not pressed to acquire startups in this space. In the case of biofuels, the inputs to their production process are also commodities. Energy producers therefore face commodity risk for both raw materials and end products. Since these markets can exhibit substantial price volatility, it makes running and managing these companies more difficult. For example, second- and third-generation biofuel startups producing ethanol or bio-crude at $80-$90 per barrel were competitive in 2007 prior to the global recession when conventional oil prices topped $100 a barrel, but most went bust when oil prices plummeted in the subsequent recession.

The challenges of backing a global commodity producer are compounded by the fact that energy and clean energy are sectors with large involvement by governments across the world. Given that clean energy technologies have not yet achieved grid parity, government policy is also critical in determining the prices of inputs and finished products. Some governments choose to either tax carbon content in conventional fuels or to buy clean energy at a premium. Others choose to subsidize clean energy companies through direct grants and subsidies or through tax-breaks. Regardless of the policy, it implies that the extent to which a given startup's product is likely to be profitable depends greatly on whether it is included in the subsidy or credit, the extent to which carbon is taxed or the price premium at which the government buys the commodity.

Policy changes and uncertainty are thus major factors hindering the potential investment by private sector players across the clean energy investment landscape. This is particularly true when the periodicity of the regulatory cycle is smaller than the investment cycle required for demonstrating commercial viability. In such an event, no one is willing to invest in the first commercial plant if they do not know what the regulatory environment is going to be by the time success has been demonstrated (based on the rules of the prior regulatory regime).

The global exposure of these markets implies that changes in the regulatory regime in one country can affect the investment landscape across the entire sector. Attractive subsidies from Spain led to a rush of investment in the solar sector there. When the government could not honor its commitments, it led to a widespread shakeout of firms in Spain. However, this not only damaged the credibility of the Spanish government in honoring its commitments towards solar subsidies, but also created suspicion among investors that other governments might face a similar fate if they did not price their subsidies correctly.

US venture capital firms are not used to investing in sectors with a large and uncertain role for government policy. Policy uncertainty implies that firms and their investors lobby for large grants that give them a buffer of capital in the short term and therefore reduce their exposure to potentially volatile longer-term government policy. They also lobby to include their particular technology in the set of firms that are eligible for benefits, while aiming to exclude others. It is not surprising that many VCs have opened up branches in Washington DC to lobby for grants to support their own startups.

5. Possible solutions

5.1 Private capital market solutions

In the absence of energy companies and utilities playing an important role in this innovation pipeline, the alternative for wide-spread innovation by startups in energy production will require the structure of the VC industry to change in key ways.

First, it will require significantly larger funds than is typical for venture capital investors. Indeed Kleiner Perkins' $500 M Green Growth Fund, and Khosla Ventures' $ 750 M fund are examples of such a trend, but the sector will probably require even larger funds to support the scale-up required by energy production companies. The majority of venture capital investors in clean technology do not have dedicated funds for this sector, and continue to raise $250-300 M funds and may need to have far greater levels of syndication, or pre-set partnerships across VCs in order to sustain the level of investment required by this sector.

The problem of raising this scale of money is compounded by the fact that investments in energy production will require longer-life funds, so that VCs can nurture startups through commercial demonstration and hence bridge the valley of death. Thus limited partners who invest in VC firms will have to commit larger sums of money that will be "locked up" for longer periods of time. Given the void in human capital required to grow and run energy production startups in the short-to-medium term, VCs will need to spend significantly longer with individual portfolio companies in order to ensure that they continue to be successful. However, the longer they need to spend helping any one company to mature, the fewer firms they can commit to working with, since each firm will take a longer proportion of their time. This has an impact on the economics of the fund and the returns to individual venture capital partners. All of these factors imply that if venture capital investment in the energy sector is to be sustained in the absence of early exit opportunities, it will require a radical reworking of the VC fund structures and terms.

Overcoming these challenges will be compounded by another factor associated with the emergence of a new industry: learning through experimentation. Investors in new technologies get feedback on their process of due diligence, the types of entrepreneurs who are most successful, and an understanding of the challenges faced by certain types of business models over the investment cycle (Goldfarb et al 2007). This is also a period when a generation of new entrepreneurs arise, driven in part by the many firms that fail due to a technology that did not work, but where the entrepreneurs developed a good working relationship with the venture capital investors. If clusters of startups in energy production do emerge in the US, the locus of such an eco-system may also involve cities such as Houston, Denver or Minneapolis where the workforce and possible buyers of energy production firms are often located. If this happens, it will also require a change in the way that VCs source deals and engage with the whole new set of other intermediaries such as lawyers, head-hunters and other service providers that will emerge to service investors who specialize in clean energy sectors.

All of these processes develop faster when the cycle times for "experimentation" by the VCs are smaller. In the context of clean energy, the feedback is much slower, driven by the dual stages of risk and the longer cycle times of clean energy. Many players therefore see a critical role for government in supporting the growth of the clean energy innovation pipeline.

5.2 Government Support

The US government has played an important role in supporting clean technology innovation in the US. However, the vast majority of this has been on the "supply side", through the direct support of specific government and university programs, grants to support pre-commercial funding of new startups through the ARPA-E program and attempts to bridge the valley of death for individual projects through the Department of Energy's loan guarantee program (Roberts, Lassiter and Nanda 2010).

While clearly very helpful in attempting to address the funding gaps inherent in the energy innovation pipeline, a key aspect of ensuring that the pipeline of new projects continue to get funding from the private sector will be to ensure that there is a vibrant set of exit opportunities for these startups before they hit the valley of death. While government guaranteed debt will help reduce some of this risk, widespread experimentation and deployment of new technologies can only take place once startups have a clear path to being acquired or going public on the capital markets. The government can therefore do more in terms of making exits easier. We note three interesting ideas that have emerged through our discussions with VCs and that are also echoed in the broader community of investors looking for solutions to the "valley of death" (Bloomberg New Energy Finance, 2010).

The first area where the government can make a significant contribution is through stable, predictable and long-term policy measures aimed at stimulating demand for clean energy. Removing uncertainty around policies reduces policy risk dramatically and makes it easier for the private capital markets to plan their investments accordingly. Furthermore, in the absence of end-user pressure to drive M&A activity, the government can create this pressure through policies such as Feed-in-Tariffs (FITs). While FITs have their most direct effect on incremental improvements of commercially proven technologies, solutions such as emerging technology auctions may be able to successfully create the appropriate demand for new technologies.

Second, the government can directly stimulate M&A activity either through the regulatory system or through corporate incentives. For example, without decoupling, utilities will have no incentive to adopt new technologies beyond anything that they are mandated to do. Renewable portfolio standards as they stand today tend to bias utilities towards adopting more mature, currently-cheaper technologies. The government can also create incentives for incumbent firms to act as first adopters for new technologies. These can effectively help to bridge the “valley of death”, create more early stage funding and drive the growth of a sufficient number of startup firms to ultimately create large firms that will compete with each other to acquire for the next generation of startups.

Finally, the government can create public-private partnership funds that can help either with first commercial testing or as mechanisms that effectively compete with the incumbents. Creating this competition can help stimulate M&A activity in the sector and hence drive the innovation pipeline (Bloomberg New Energy Finance, 2010).

6. Conclusion

Venture capital has been the engine behind the widespread innovation in the United States over the last several decades. To what extent is it adequately positioned to help with the rapid commercialization of clean energy technologies over the coming years?

There has been a rapid inflow of venture capital backing clean energy startups in the past few years. While there are several startups in clean energy that are well-suited to the traditional venture capital investment model, our analysis highlights a number of structural challenges related to VC investment in the sector that are particularly acute for startups involved in the *production* of clean energy.

Many have argued that continued innovation in power production (which accounts for 40% of CO_2 emissions) is of great importance from both an environmental and an energy security perspective. We argue that longer-term innovation in this space by venture-backed startups in the US will depend critically on the ability of the innovation ecosystem to adapt to the different structural characteristics of the clean energy sector.

One of the most important bottlenecks threatening the innovation pipeline in energy production is the inability of VCs to exit their investments at the appropriate time. This hurdle did exist in industries such as biotechnology and communications networking that faced a similar problem when they first emerged, and was ultimately overcome by changes in the innovation ecosystem. However, incumbents in the oil and power sector are different in two respects. First, they are producing a commodity and hence face little end-user pressure to adopt new technologies. Second, they do not tend to feel as threatened by potential competition from these clean energy startups, given the market structure and regulatory environment in the energy sector. While this is particularly true for energy production, this challenge is also present for startups in the energy efficiency and transportation sub-sectors. We highlight that the problem is unlikely to get solved without the active involvement of government. Even if it does, historical experience suggests it may take several years.

While the US government has taken important steps to facilitate the funding of radical innovations in clean energy, a key aspect of the innovation ecosystem that will be required to make this sustainable will be to jumpstart an active M&A market for clean energy startups. This will effectively bridge the valley of death in both the capital markets and the labor markets, as well as stimulate more upstream funding of clean technology startups by venture capital investors. While a direct policy of facilitating exit for venture investors might be expected to generate some political resistance, we highlight some options that VCs have outlined that may go some way towards resolving the bottleneck.

References

Bloomberg New Energy Finance (2010) “Crossing the Valley of Death; Solutions to the next generation clean energy project financing gap” June 2010 white paper

Goldfarb, B., D. Kirsch and D. Miller (2007) “Was there too Little Entry in the Dot Com Era?” Journal of Financial Economics 86(1): 100-144.

Gompers, P. "Optimal Investment, Monitoring, and the Staging of Venture Capital." Journal of Finance 50(4): 1461-1489.

Gompers, P. and J. Lerner. "An Analysis of Compensation in the U.S. Venture Capital Partnership." Journal of Financial Economics 51(1): 3-44.

Gompers, P. and J. Lerner (1999). The Venture Capital Cycle, MIT Press, Cambridge, MA.

Hellman, T. and M. Puri (2002). "Venture Capital and the Professionalization of Start-up Firms: Empirical Evidence" Journal of Finance 57(1): 169-197

Henderson, R. and K. Clark (1990). "Architectural Innovation - the Reconfiguration of Existing Product Technologies and the Failure of Established Firms." Administrative Science Quarterly 35(1): 9-30.

Hsu, D. H. (2004). "What do Entrepreneurs pay for Venture Capital Affiliation?" Journal of Finance 59(4): 1805-1844

Kaplan, S and A. Schoar (2005) “Private Equity Performance: Returns, Persistence and Capital Flows” Journal of Finance 60(4): 1791-1823

Kaplan, S. and P. Stromberg (2003). "Financial contracting theory meets the real world: An empirical analysis of venture capital contracts." Review of Economic Studies 70(2): 281-315.

Kerr, W. and R. Nanda (2010) "Financing Constraints and Entrepreneurship." In Handbook on Research on Innovation and Entrepreneurship, edited by David Audretsch, Oliver Falck and Stephan Heblich. Cheltenham, UK: Edward Elgar Publishing, Inc., forthcoming

Kortum, S. and J. Lerner (2000). "Assessing the Contribution of Venture Capital to Innovation." Rand Journal of Economics 31: 674-692.

Nanda, R. and M. Rhodes-Kropf (2010) “Financing Risk and Bubbles of Innovation”, HBS Working Paper

Roberts, M., J. Lassiter and R. Nanda (2010) "U.S. Department of Energy & Recovery Act Funding: Bridging the "Valley of Death"." Harvard Business School Case 810-144.

Sorensen, Morten (2007) “How Smart is Smart Money: A Two-Sided Matching Model of Venture Capital,” Journal of Finance 62: 2725-2762.